

What is claimed is:

1. A nitride semiconductor light-emitting device comprising:

5 an active layer of a quantum well structure comprising a nitride semiconductor containing indium and gallium, and having first and second main surfaces;

10 a first p-type clad layer comprising a p-type nitride semiconductor containing aluminum and gallium, and provided in contact with said second main surface of the active layer;

15 a second p-type clad layer comprising a p-type nitride semiconductor containing aluminum and gallium, having a larger band gap than that of said first p-type clad layer, and provided on said first p-type clad layer; and

an n-type semiconductor layer provided in contact with said first main surface of the active layer.

20 2. The device according to claim 1, wherein said first p-type clad layer has a thickness with in a range of 10 angstroms to 1.0  $\mu$  m.

3. A nitride semiconductor light-emitting device comprising:

25 an active layer comprising of a quantum well structure comprising a nitride semiconductor containing indium and gallium, and having first and second main surfaces;

a first n-type clad layer made of an n-type

nitride semiconductor containing aluminum and gallium  
or of an n-type GaN, and provided in contact with said  
first main surface of the active layer, said first n-  
type clad layer having a thickness within a range of  
5 10 angstroms to 1.0  $\mu$  m;

a second n-type clad layer comprising an n-type  
nitride semiconductor having a larger band gap than  
that of said first n-type clad layer, and provided on  
said first n-type clad layer; and

10 a p-type semiconductor layer provided in contact  
with said second main surface of the active layer.

4. The device according to claim 3, wherein said  
first n-type clad layer has a thickness within a range  
of 100 angstroms to 1.0  $\mu$  m.

15 5. A nitride semiconductor light-emitting device  
comprising:

an active layer of a quantum well structure  
comprising a nitride semiconductor containing indium  
and gallium, and having first and second main surfaces;

20 a first n-type clad layer made of an n-type  
nitride semiconductor containing aluminum and gallium,  
or of an n-type GaN, and provided in contact with said  
first main surface of the active layer;

25 a second n-type clad layer comprising an n-type  
nitride semiconductor having a larger band gap than  
that of said first n-type clad layer, and provided on  
said first n-type clad layer;

a first p-type clad layer comprising a p-type nitride semiconductor containing aluminum and gallium, and provided in contact with said second main surface of the active layer; and

5 a second p-type clad layer comprising a p-type nitride semiconductor containing aluminum and gallium, having a larger band gap than that of said first p-type clad layer, and provided on said first p-type clad layer.

10 6. The device according to claim 5, wherein said first p-type clad layer has a thickness within a range of 10 angstroms to  $1.0 \mu\text{m}$ .

15 7. The device according to claim 5, wherein said first n-type clad layer has a thickness within a range of 10 angstroms to  $1.0 \mu\text{m}$ .

20 8. A nitride semiconductor light-emitting device comprising an active layer of a quantum well structure comprising a nitride semiconductor containing indium and gallium and interposed between an n-type nitride semiconductor layer and a p-type semiconductor layer, said p-type semiconductor layer including a p-type clad layer provided in contact with said active layer, said p-type clad layer comprising a p-type nitride semiconductor containing aluminum and gallium and  
25 having a thickness within a range of 10 angstroms to  $1.0 \mu\text{m}$ .

9. The device according to claim 8, wherein said

n-type nitride semiconductor layer is made of an n-type GaN or an n-type nitride semiconductor containing indium and gallium.

5 10. A nitride semiconductor light-emitting device comprising an active layer of quantum well structure interposed between an n-type nitride semiconductor layer and a p-type semiconductor layer, said active layer comprising a nitride semiconductor containing indium and gallium, and provided with a well layer  
10 having a thickness of not more than 70 angstroms.

11. The device according to claim 10, wherein said active layer is of a multi-quantum well structure including a barrier layer having a thickness of not more than 150 angstroms.

15 12. A nitride semiconductor light-emitting device comprising an active layer of a quantum well structure having first and second main surfaces, and comprising a nitride semiconductor containing indium and gallium; and a first n-type clad layer comprising an n-type  
20 nitride semiconductor containing indium and gallium.

13. The device according to claim 12, wherein a total thickness of said active layer and said first n-type clad layer is 300 angstroms or more.

25 14. The device according to claim 12, further comprising an n-type contact layer formed of an n-type GaN and provided in contact with said first n-type clad layer or said first main surface of the active layer.

15. The device according to claim 12, further comprising a second n-type clad layer comprising an n-type nitride semiconductor containing aluminum and gallium, and provided in contact with said first n-type  
5 clad layer.

16. The device according to claim 12, further comprising an n-type contact layer formed of an n-type GaN and provided in contact with said second n-type clad layer.

10 17. A nitride semiconductor light-emitting device comprising an active layer of a quantum well structure having first and second main surfaces, and comprising a nitride semiconductor containing indium and gallium; and a first p-type clad layer comprising a p-type  
15 nitride semiconductor containing indium and gallium.

18. The device according to claim 17, wherein a total thickness of said active layer and said first p-type clad layer is 300 angstroms or more.

19. The device according to claim 17, further  
20 comprising a p-type contact layer formed of a p-type GaN and provided in contact with said first p-type clad layer.

20. The device according to claim 17, further comprising a second p-type clad layer made of a p-type  
25 nitride semiconductor and provided in contact with said first p-type clad layer.

21. The device according to claim 20, further

comprising a p-type contact layer formed of a p-type GaN and provided in contact with said second p-type clad layer.

22. A nitride semiconductor light-emitting device  
5 comprising:

an active layer comprising a nitride semiconductor containing indium and gallium, and having first and second main surfaces;

10 a first n-type clad layer comprising an n-type nitride semiconductor not containing aluminum, and provided in contact with said first main surface of the active layer; and

15 a p-type clad layer comprising a p-type nitride semiconductor and having a surface region, at least said surface region comprising a p-type nitride semiconductor containing aluminum and gallium, said p-type clad layer being provided in contact with said second main surface of the active layer.

20 23. The device according to claim 22, wherein said p-type clad layer is constituted by a first p-type layer comprising a p-type nitride semiconductor containing no aluminum and provided in direct contact with said second main surface of the active layer, and a second p-type layer comprising a p-type nitride  
25 semiconductor containing aluminum and gallium and provided on said first p-type layer.

24. The device according to claim 22, wherein said

active layer is of a quantum well structure.

25. The device according to claim 22, wherein a total thickness of said active layer and said first n-type clad layer is 300 angstroms or more.

5        26. The device according to claim 22, wherein a total thickness of said active layer, said first n-type clad layer and said first p-type layer of said p-type clad layer is 300 angstroms or more.

10        27. The device according to claim 22, further comprising a second n-type clad layer comprising an n-type nitride semiconductor containing aluminum and gallium, and provided in contact with said first n-type clad layer.

15        28. The device according to claim 22, further comprising an n-type contact layer formed of an n-type GaN and provided in contact with said first n-type clad layer.

20        29. The device according to claim 27, further comprising an n-type contact layer formed of an n-type GaN and provided in contact with said second n-type clad layer.

25        30. The device according to claim 22, further comprising a p-type contact layer formed of a p-type GaN and provided in contact with said p-type clad layer.

31. The device according to claim 22, further comprising, as a light reflecting film, a first

multi-layered film comprising at least two nitride semiconductor layers differing in composition, and provided on an outer side of said first n-type clad layer.

5           32. The device according to claim 22, further comprising, as a light reflecting film, a second multi-layered film comprising at least two nitride semiconductor layers differing in composition and provided on an outer side of said p-type clad layer.

10           33. The device according to claim 31, further comprising an n-type contact layer formed of an n-type GaN and provided in contact with said first multi-layered film.

15           34. The device according to claim 32, further comprising a p-type contact layer formed of a p-type GaN and provided in contact with said second multi-layered film.

20           35. A nitride semiconductor light-emitting device comprising an active layer of a quantum well structure comprising a nitride semiconductor; an negative electrode; a positive electrode; an n-type GaN contact layer provided in contact with said negative electrode; and a p-GaN contact layer provided in contact with said positive electrode.

25           36. A nitride semiconductor light-emitting device comprising an active layer having first and second main surfaces, and comprising a nitride semiconductor



containing indium and gallium; and a first n-type clad layer comprising an n-type nitride semiconductor containing indium and gallium, having a larger band gap than said active layer, and being provided in contact  
5 with said first main surface of the active layer.

37. A nitride semiconductor light-emitting device comprising an active layer having first and second main surfaces, and comprising a nitride semiconductor containing indium and gallium; and a first p-type clad layer comprising a p-type nitride semiconductor  
10 containing indium and gallium, having a larger band gap than said active layer, and being provided in contact with said second main surface of the active layer.

38. The device according to claim 36, further  
15 comprising a second n-type clad layer made of an n-type nitride semiconductor containing aluminum and gallium, having a larger band gap than that of the first n-type clad layer, and provided in contact with said first n-type clad layer.

39. The device according to claim 37, further  
20 comprising a second p-type clad layer comprising a p-type nitride semiconductor containing aluminum and gallium, having a larger band gap than that of the first p-type clad layer, and provided in contact with  
25 said first p-type clad layer.

40. The device according to claim 36, further comprising an n-type contact layer formed of an n-type

GaN and provided in contact with said first n-type clad layer or said first main surface of the active layer.

41. The device according to claim 38, further comprising an n-type contact layer formed of an n-type GaN and provided in contact with said second n-type clad layer.

42. The device according to claim 37, further comprising a p-type contact layer formed of a p-type GaN and provided in contact with said first p-type clad layer.

43. The device according to claim 39, further comprising a p-type contact layer formed of a p-type GaN and provided in contact with said second p-type clad layer.

44. The device according to claim 41, further comprising, as a light reflecting film, a first multi-layered film comprising at least two nitride semiconductor layers differing in composition and provided between said second n-type clad layer and said n-type contact layer, or in said n-type contact layer.

45. The device according to claim 44, wherein one of said two nitride semiconductor layers forming said first multi-layered film is a nitride semiconductor containing indium and gallium, or GaN; and the other is a nitride semiconductor containing aluminum and gallium.

46. The device according to claim 43, further

comprising, as a light reflecting film, a second multi-layered film comprising at least two nitride semiconductor layers differing in composition and provided between said second p-type clad layer and said p-type contact layer, or in said p-type contact layer. . .

47. The device according to claim 46, wherein one of said two nitride semiconductor layers forming said second multi-layered film is a nitride semiconductor containing indium and gallium, or GaN; and the other is a nitride semiconductor containing aluminum and gallium.

48. A nitride semiconductor light-emitting device comprising:

an active layer comprising a nitride semiconductor containing indium and gallium, and having first and second main surfaces;

a first n-type clad layer comprising an n-type nitride semiconductor containing indium and gallium, having a larger band gap than that of said active layer, and provided in contact with said first main surface of the active layer;

a first p-type clad layer comprising a p-type nitride semiconductor containing indium and gallium, having a larger band gap than that of said active layer, and provided in contact with said second main surface of the active layer;

a second n-type clad layer comprising an n-type

nitride semiconductor containing aluminum and gallium, having a larger band gap than that of said first n-type clad layer, and provided in contact with said first n-type clad layer; and

5           a second p-type clad layer comprising a p-type nitride semiconductor containing aluminum and gallium, having a larger band gap than that of said first p-type clad layer, and provided on said first p-type clad layer.

10           49. The device according to claim 48, further comprising a p-type contact layer formed of a p-type GaN and provided in contact with said second p-type clad layer, and an n-type contact layer formed of an n-type GaN and provided in contact with said second n-type clad layer.

15           50. A nitride semiconductor light-emitting device comprising an active layer comprising a nitride semiconductor containing at least indium and interposed between a first n-type clad layer comprising an n-type nitride semiconductor having a smaller thermal  
20           expansion coefficient than that of said active layer and a first p-type clad layer comprising a p-type nitride semiconductor having a smaller thermal expansion coefficient than that of said active layer,  
25           wherein said active layer is of a single-quantum well structure or of a multi-quantum well structure, thereby to emit a light of lower energy than the inherent band

gap energy of said nitride semiconductor forming said active layer.

51. The device according to claim 50, wherein said active layer comprises a well layer having a thickness  
5 of not more than 100 angstroms.

52. The device according to claim 50, wherein said first n-type clad layer is formed of an n-type  $\text{In}_x\text{Ga}_{1-x}\text{N}$  where  $0 \leq x < 1$ .

53. The device according to claim 50, wherein said  
10 first p-type clad layer is formed of a p-type  $\text{Al}_y\text{Ga}_{1-y}\text{N}$  where  $0 \leq y \leq 1$ .

54. The device according to claim 50, further comprising a second n-type clad layer comprising an n-type nitride semiconductor and provided in contact with  
15 said first n-type clad layer.

55. The device according to claim 54, wherein said second n-type clad layer is formed of an n-type  $\text{Al}_a\text{Ga}_{1-a}\text{N}$  where  $0 \leq a \leq 1$ .

56. The device according to claim 50, further  
20 comprising a second p-type clad layer comprising a p-type nitride semiconductor and provided in contact with said first p-type clad layer.

57. The device according to claim 56, wherein said  
25 second p-type clad layer is formed of a p-type  $\text{Al}_b\text{Ga}_{1-b}\text{N}$  where  $0 \leq b \leq 1$ .

58. The device according to claim 50, wherein said active layer is doped with a donor impurity and/or

an acceptor impurity.

59. A nitride semiconductor light-emitting device comprising a first n-type clad layer made of an n-type nitride semiconductor containing indium or of an n-type GaN; and an active layer comprising a nitride semiconductor containing indium, having a larger thermal expansion coefficient than that of said first n-type clad layer and provided in contact with said first n-type clad layer, wherein said active layer is of a single-quantum well structure or of a multi-quantum well structure, thereby to emit a light of lower energy than the inherent band gap energy of said nitride semiconductor forming said active layer.

60. The device according to claim 59, wherein a total thickness of said active layer and said first n-type clad layer is 300 angstroms or more.

61. A nitride semiconductor light-emitting device comprising an active layer comprising a nitride semiconductor containing indium; and a first p-type clad layer comprising a p-type nitride semiconductor containing aluminum, having a larger thermal expansion coefficient than that of said active layer and provided in contact with said active layer wherein said active layer is of a single-quantum well structure or of a multi-quantum well structure, thereby to emit a light of lower energy than the inherent band gap energy of said nitride semiconductor forming said active layer.

62. A nitride semiconductor light emitting diode device comprising:

a substrate;

5 an n-type layer formed of n-type GaN provided over said substrate;

an active layer of a single-quantum well structure or a multi-quantum well structure comprising InGaN and provided on said n-type layer;

10 a first p-type layer formed of p-type AlGa<sub>N</sub> and provided on said active layer; and

a second p-type layer formed of p-type GaN and provided on said first p-type layer.